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Shadowing Interference in a Dichotic Listening Task with Categorized and Uncategorized Word Lists

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SHADOWING INTERFERENCE IN A DICHOTIC LISTENING TASK WITH CATEGORIZED AND UNCATEGORIZED WORD LISTS

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LISTENING TASK WITH CATEGORIZED

AND UNCATEGORIZED WORD LISTS

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The purpose of this thesis was twofold: to investigate the effects of categorized versus uncategorized material on selective attention and to test predictions derived from Filter Theory (Broadbent, 1958), Response Selection Theory (Deutsch and Deutsch, 1963), and Attenuation Theory (Treisman, 1969). Subjects performed a dichotic-listening task in which they shadowed a list of words presented to one ear (i.e., relevant message) while trying to ignore a simultaneously presented list of words on the other ear (i.e., irrelevant message). Lists were 16 words in length and consisted of either categorized words (C) or uncategorized words (U) presented at a rate of one word per second. Four conditions were generated by using all pairings of C lists and U lists for relevant versus irrelevant messages: U-U, U-C, C-U, and C-C. Note that the left-most symbol designates the relevant message and the right-most symbol designates the irrelevant message. Subjects received two presentations of each of the four conditions. Measurements of pupil size were taken twice (9 sec and 5 sec) before the presentation of each dichotic trial (i.e., baseline measures) and at six positions (1, 4,

7, 10, 13, and 16) in the word lists (i.e., trial measures). Since each subject received eight experimental trials (two trials in each of four conditions), there were a total of four baseline measurements and twelve trial measurements for each condition. In each condition the four baseline measurements were averaged and the two trial measurements were averaged at each of the six positions. The mean baseline was subtracted from each of the six position means in each condition. These mean difference scores were used as the basis for one analysis. Shadowing errors (i.e., omissions of relevant words, mispronunciations of relevant words, or intrusions of irrelevant words) were scored by quadrants separately for each of the four conditions. The first quadrant consisted of the first through fourth words, the second quadrant consisted of the fifth through eighth words, and so on. Error scores were then converted to percents and used as the basis for a second analysis.

A 4 by 6 ANOVA with repeated measures on both factors (condition and position, respectively) was used to analyze the pupil size data. The results indicated that pupil size decreased across serial position in a similar fashion for all conditions. Furthermore, pupil size did not differ significantly among the four conditions. A 4 by 4 ANOVA with repeated measures on both factors (condition and quadrant, respectively) was used to analyze the error rate data. The results indicated an interaction between

condition and quadrant. The C-U and C-C conditions resulted in a relatively constant error rate across quadrants, while the U-U and U-C conditions exhibited an increasing error rate across quadrants. The results of the two analyses are discussed in terms of their implications for Filter Theory, Response Selection Theory, and Attenuation Theory.

INTRODUCTION

Interest in the concept of attention in academic psychology began in the late nineteenth century. William James, one of the first experimental psychologists to consider the role of attention in the processing of information, attempted in 1890 to describe relevant psychological processes in The Principles of Psychology (Broadbent, 1958). Although James' observations provided a useful framework for studying attention, he did not empirically validate his observations. Therefore, many issues concerning how the attention process operates are still unresolved today. One of the aspects of attention which interested James involves the perception of stimuli to which we are not intentionally attending (Norman, 1969). Interest in selective attention has been concerned primarily with the role of such stimuli in the processing of information.

Selective attention deals with the ability of an organism to selectively focus upon some stimuli, or aspects of stimulation, in preference to others (Kahneman, 1973). The "cocktail-party phenomenon" (Cherry, 1953) illustrates the concept of selective attention. Imagine a crowded cocktail party at which there are various sounds and conversations. Two people are engaged in social interaction. In order to understand one another, each person must selectively attend to the other person's conversation and try to ignore the conversations of the other people in the room. Although the two persons are able to focus attention primarily on the conversation of the other, hearing one's own name spoken by a third individual usually results in a shifting of attention to that third person.

The cocktail party phenomenon gives rise to several questions. How does one person selectively attend to the conversation of another person while attempting to ignore the conversations of nearby people? Is perception of the content of the interactant's conversations affected by the loudness, number, or content of the conversations of the other people? If so, to what extent? How much do the interactants perceive of the conversations they are trying to ignore? How does one often hear one's own name while supposedly trying to ignore the content of other conversations? Experimental investigations of selective attention have provided answers to some of these questions, while others are still open to debate.

This thesis is the product of an attempt to experimentally examine some certain factors that may contribute to the ability of a person to focus attention on relevant information while trying to ignore irrelevant information.

LITERATURE REVIEW

When two stimuli are presented at once (e.g., two conversations at a cocktail party), often only one (i.e., relevant message) is fully perceived and receives a response. The other stimulus (i.e., irrelevant message) is not responded to because that stimulus does not receive sufficient attention to be fully perceived or because the stimulus is fully perceived but the person either chooses not to respond or is unable to respond. Sometimes both stimuli are fully perceived as, for example, when one hears one's own name from the irrelevant source of stimulation. However, when both stimuli are perceived, the elicited responses are often made in succession rather than concurrently. The fact that irrelevant stimuli frequently receive either no response or a delayed response suggests the presence of a stage of internal processing which operates on one stimulus or one response at a time (Kahneman, 1973). In other words, a stage apparently exists wherein parallel processing of several inputs switches to serial processing of stimuli or to successive emission of responses.

The stage at which parallel processing seems to switch to serial processing or to successive responding has often been referred to as the "bottleneck" of the attention process. Structural models of selective attention are based on the assumption that this bottleneck constitutes an inherent limitation in the attention mechanism, which automatically limits one's ability to perceive (Broadbent, 1958) or to respond to (Deutsch and Deutsch, 1963) simultaneously presented stimuli. Interference occurs when the same mechanism is required to conduct two incompatible operations at the same time. However, Treisman (1964c) and Kahneman (1973) disagree with this view of selective attention. Thus, they have offered theories which seek to explain limitations in perceiving simultaneously presented stimuli as being due to causes other than a structural bottleneck.

Treisman (1969) proposes that irrelevant stimulation is attenuated or suppressed in intensity rather than being blocked or precluded from further processing. Interference occurs when irrelevant stimulation is not sufficiently attenuated to allow complete processing of relevant stimulation. Kahneman (1973), on the other hand, postulates the existence of a pool of processing capacity or mental resources, which can be allocated according to the demands of the task being undertaken. Interference occurs when the demands of the task exceed the available supply of processing capacity. As can be ascertained, major differences exist in the manner in which selective attention is thought to occur. However, before these four models of selective attention can be further elaborated and analyzed, primary methods of investigating selective attention must be discussed.

<u>Methods of Investigating Selective Attention</u>

Experiments concerning the nature of selective attention have centered on tasks that require the subject to "select inputs." Kahneman (1973) states that "a person is said to select inputs when he focuses attention exclusively on stimuli that originate from a particular source or share some other characteristic feature" (p. 112). In dealing with the ability to select a <u>relevant</u> input in the presence of an <u>irrelevant</u> input, many researchers have used the shadowing task. In a shadowing task, the subject repeats aloud every word of one message while attempting to ignore another simultaneously presented message. Messages may be presented either monaurally, binaurally, or dichotically. <u>Monaural</u> presentation occurs when two messages are presented to the same ear. <u>Binaural</u> presentation occurs when both messages are presented to each ear. <u>Dichotic</u> presentation occurs when one message is presented to one ear, while the other message is presented to the other ear.

Failure to exclude irrelevant inputs in a shadowing task can be assessed by a reduction in shadowing accuracy, by memory of irrelevant information, by an increased response latency to relevant stimuli, or by physiological concomitants which reflect the effort involved in shadowing. Reduction in shadowing accuracy has been measured through omissions of relevant words, errors in pronunciation of one or more phonemes of relevant words, intrusions of one or more phonemes from an irrelevant message, and intrusions of irrelevant words (e.g., Treisman, 1960; 1964c). Memory of irrelevant information has been measured through recognition (e.g., Cherry, 1953; Treisman, 1964a) and recall (e.g., Broadbent, 1954; Cherry, 1953; Moray, 1959).

However, several investigators have argued that memory of irrelevant information and error rate in shadowing are relatively insensitive measures of the amount of processing that irrelevant information received at the time of presentation. Irrelevant information may be perceived but not remembered and may hinder performance without actually producing overt errors in shadowing the relevant message. Thus, these investigators have sought to keep error rate low while opting for a variety of other measures. Some have used vocal reaction time (i.e., response latency) to relevant stimuli (e.g., Lewis, 1970; Treisman, Squire, and Green, 1974), while others have chosen psychophysiological measures, such as galvanic skin response (e.g., Corteen and Dunn, 1974; Corteen and Wood, 1972; Wardlaw and Kroll, 1976), electrodermal response (e.g., Dawson and Schell, 1982), and pupil dilation (Ambler, Fisicaro, and Proctor, 1976; Kahneman, Peavler, and Onuska, 1968). Regardless of the specific measure of interference employed in a study, models of selective attention must account for the results of experimental investigations. The ability of these models to do so will be considered as the models are formally presented.

Filter Theory (Broadbent 1958)

The publication in 1958 of Broadbent's book, Perception and Communication, is considered by many investigators of attention as one of the landmarks in the rise of information-processing psychology (Allport, 1980). Broadbent (1958) assumed a sequence of three elements in his Filter Theory of attention: a short-term store (S-system), a selective filter, and a limited capacity channel (P-system). Simultaneously presented stimuli enter the S-system in parallel and are analyzed there for physical characteristics (e.g., intensity, pitch, and spatial localization of sounds). The filter then selects the relevant message according to some physical characteristic and temporarily prevents the irrelevant message from undergoing further analysis. The P-system then conducts a more elaborate analysis of stimuli accepted as the relevant message. Stimuli that comprise the irrelevant message are held in the S-system for a short period of time and may be analyzed by the P-system if attention is switched from the relevant message to the irrelevant message. However, if attention is not switched, the irrelevant message merely decays and is filtered out before the contents receive complete analysis.

One of the studies upon which Broadbent based Filter Theory was that of Cherry (1953). Using a dichotic-listening task, Cherry (1953) required subjects to shadow newspaper passages presented to one ear and to ignore other newspaper passages which were simultaneously presented to the other ear. During the shadowing task, the nature of the irrelevant message was changed as follows: the irrelevant message began and ended with English spoken in a male voice, as in the relevant message. However, the central portion of the irrelevant message was switched to either female-spoken English in a high-pitched voice, reversed male speech having the same spectrum as normal speech but with no words or meaning, a steady 400 cycles-per-second (cps) pure tone produced by an oscillator, or a German message spoken by an Englishman. After the experiment all subjects were questioned as to any changes they had observed and as to the content of the irrelevant message.

Cherry (1953) found that subjects were unable to report any changes in the irrelevant message when the switch was to a German message or reversed speech. Although subjects were able to detect the change in voice from male to female, none of the subjects could report any of the content of the irrelevant message. However, subjects were able to recognize the change from the male-spoken English to the 400-cps pure tone. These results suggest that the irrelevant message was analyzed for certain physical characteristics (e.g., changing from a male to female voice) but that detailed aspects, such as language, individual words, or semantic content, were not perceived.

Cherry (1953) also found in another experiment that if the irrelevant and relevant messages were identical and the lag time between presentation of the messages was gradually reduced, subjects noticed that the messages were identical with delays between 2 and 6 seconds. However, Cherry did not state which message led the other. If the relevant message led, it might have been held in the S-system as suggested by Broadbent (1958). The comparison with the irrelevant message could then have been made prior to the filter on the basis of sounds rather than of word meaning. However, if the irrelevant message led, this would suggest that material presented to this ear had been monitored, had passed through the filter, and was then compared with the relevant message on the basis of word meaning. Thus, Treisman (1964a) sought to clarify the results obtained by Cherry.

Treisman (1964a) used a dichotic-listening task and required subjects to shadow passages of English prose (100 words each) recorded in a female voice. Each passage lasted 40 seconds. The irrelevant message consisted of either the same recording of the relevant message, the same relevant message but recorded in a male voice, or a French translation of the relevant message recorded in the same female voice. The lag time between presentation of identical words in relevant and irrelevant messages was varied to give temporal differences of 6.0, 4.5, 3.0, 1.5, or 0 seconds. When the relevant message led, subjects recognized the identity of the two messages when the lag was about 5 seconds. When the irrelevant message led, subjects recognized the identity at an interval of 1.5 seconds. These results were obtained even when the two messages were spoken in different voices. Treisman also found that, when the relevant message was in English and the irrelevant message was a French translation of the relevant message, bilingual listeners often recognized the identity of the messages. Thus, the filter proposed by Broadbent does appear to allow some analysis of the irrelevant message beyond that of physical characteristics.

Another study upon which Filter Theory was based was that of Broadbent (1954). Broadbent presented subjects with two lists of three digits each. Digits were presented dichotically and simultaneously at a rate of one digit per

1.5 seconds. Broadbent found that recall in successive order (i.e., all stimuli from one ear followed by all those from the other ear) was superior to recall in alternating order (left ear/right ear, left ear/right ear, left ear/right ear). Broadbent also found similar results when the digits were presented at a faster rate. However, he did find that, when the rate of presentation was slower than one digit per 2 seconds, subjects were able to recall the digits in alternating order. Evidently, this relatively long delay effectively allowed subjects to switch attention between messages held in the S-system prior to the arrival of the next pair of digits.

Two dichotic-listening experiments by Moray (1959) provide some support for Filter Theory. In both experiments, Moray required subjects to shadow a prose passage and to ignore a list of unrelated words presented to the other ear. The presentation rate was approximately 150 words per minute. The list of words, which constituted the irrelevant message, was faded in after shadowing began and was then faded out before shadowing ended. He found that the content of the irrelevant message could not be recalled. In another experiment, Moray found that subjects showed no advantage in attempting afterward to learn digits which had been interspersed with words in the irrelevant message. These results tentatively suggest that the irrelevant message had not been analyzed for content in the

P-system. However, Moray also found that subjects recognized some of the content of the irrelevant message if it was preceded by the subject's name. Thus, Moray concluded that subjectively "important" messages could penetrate the filter proposed by Broadbent.

In light of Moray's (1959) findings, Treisman (1960) wanted to discover whether an expectancy based on transitional probabilities between words (i.e., contextual cues) would be sufficiently strong to override the dichotic localization cues. Moray had suggested that important messages, such as one's own name, could penetrate the selective filter. Treisman sought to determine whether words in the irrelevant message could also penetrate the selective filter if they were made "highly probable" instead of important.

Treisman (1960) asked subjects to shadow one of two dichotically presented passages and to ignore the passage presented to the other ear. The passages were each 50 words long and were of four different kinds: excerpts from a novel (Lord Jim by Conrad), exerpts from a technical discussion of language (Signs, Language and Behavior by Morris), 8th-order, and 2nd-order statistical approximations to English. The higher statistical approximation (8th order) is more similar to comprehensible prose than is the 2nd order (Miller and Selfridge, 1950).

In each recording the messages were switched from one ear to the other at some point between the 20th and 35th words. Treisman found that 15 of the 18 subjects did repeat one or two words from the irrelevant message after the two messages were switched. She also found that subjects were significantly more likely to repeat words from the irrelevant message after the switch if they were following excerpts from either book than if they were following either statistical approximation to English. Treisman concluded from these results that the "selective filter" proposed by Broadbent does seem to allow one or two probable words through from the rejected ear when the transitional probabilities of the relevant message are suddenly contradicted.

In summary, Broadbent (1958) has provided a model of selective attention which has aided both research and the development of other models. However, strong evidence has been obtained which contradicts his postulation of a bottleneck (i.e., filter) at an early stage of perceptual analysis. This evidence led Deutsch and Deutsch (1963) to conclude that the bottleneck must be located "deeper" in the processing sequence.

Response Selection Theory (Deutsch and Deutsch, 1963)

Deutsch and Deutsch (1963) made a radical revision of Filter Theory as they asserted that "a message will reach the same perceptual and discriminatory mechanism whether attention is paid to it or not" (p. 83). They postulated that "central structures" (i.e., stores of known words) are activated by sensory stimulation. However, the degree to which these structures are activated is independent of the amount of attention devoted to the source of stimulation. The central structure that is excited by a specific quality or attribute of a stimulus is given a preset weighting of "importance" which may reflect either momentary intentions (e.g., animal names are currently relevant) or enduring dispositions (e.g., one's own name is always relevant). Among concurrently active central structures, the one with the highest weighting of importance will inhibit responses to other central structures and control both awareness and response. Thus, Response Selection Theory locates the transition from parallel to serial processing closer to the ultimate response than does Filter Theory.

Since Response Selection Theory assumes that all sensory stimuli which infringe upon a person are perceptually analyzed at the highest level, the meanings of all stimuli are processed in parallel and without interference (Kahneman, 1973). This process results in all features of all stimuli being analyzed to provide a final degree of "importance" for that stimulus. The stimulus possessing the greatest degree of importance may then be selected for response and for memory, while those of lesser importance would be rapidly forgotten.

Lewis (1970) attempted to provide differential support for Filter Theory versus Response Selection Theory. He noted that most of the experiments supporting Filter Theory had been based on the rather insensitive method of recall or on a method requiring subjects to make an overt response to irrelevant stimuli while simultaneously responding to a relevant task. He added that many of the findings inconsistent with Filter Theory and, by default, consistent with Response Selection Theory were obtained from inadequately controlled experiments. Thus, when subjects had been able to report stimuli from the irrelevant message, one must question whether they could have temporarily switched attention to that message during the task. Therefore, in order to provide a definitive statement as to the level of processing received by an irrelevant message, Lewis attempted to adequately control the experimental method by establishing three criteria:

> (a) Sequences of unrelated words were used rather than prose with unspecifiable redundancies; (b) presentation rate was established such that S could not switch to the unattended message without losing part of the attended message (one word per .66 sec); and (c) relatively errorless shadowing was required (p. 226).

Using vocal reaction time (RT) to relevant stimuli as the dependent variable, Lewis (1970) required subjects to shadow a list of words presented to one ear, while a different list of words was simultaneously presented to the other ear. He found that RT increased when a synonym of the shadowed word was presented simultaneously to the other ear. This result indicated to Lewis that the irrelevant message had received full perceptual (i.e., semantic) analysis and, therefore, supported Response Selection Theory.

Treisman, Squire, and Green (1974) questioned the findings of Lewis (1970). They replicated the experiment of Lewis and found that the increased reaction time for synonyms occurred only for synonyms presented early in the list. Treisman et al. also found that the increased reaction time was due to a few long response latencies rather than an increase on every trial. They suggested that "it takes a short time for capacity to become fully occupied by one channel and for the other to be effectively excluded from semantic analysis" (p. 645). Treisman et al. thus concluded that their results demonstrated a lack of full perceptual analysis of irrelevant stimuli and, as such, did not provide support for Response Selection Theory.

Ambler, Fisicaro, and Proctor (1976) extended the line of research by Lewis (1970) and Treisman, et al. (1974). Ambler et al. required subjects to shadow either one-digit or two-digit numbers and to ignore the irrelevant message, which consisted of either one syllable words or white noise. Relevant and irrelevant messages were presented simultaneously at a rate of one number per second.

Measurements of pupil size were taken at five positions in the relevant message. Ambler et al. found that pupil size decreased as serial position increased in all four conditions. They suggested that their results were consistent with the proposal by Treisman et al. that interference from the irrelevant message decreases over time because time is required for attention to become focused on the relevant message. Ambler et al. also found a significant difference between the two types of irrelevant messages, with words producing a larger mean difference in pupil size across serial position than did white noise. These results indicate that relatively gross differences in the nature of the irrelevant message produce significant differences in the difficulty of a shadowing task.

Ambler et al. (1976) designed their next experiment to determine whether shadowing-task difficulty was sensitive to finer differences in the relationship of the irrelevant message to the relevant message. Relevant messages were composed of letters, whereas irrelevant messages were composed of either letters, digits, words, or prose. Ambler et al. argued that, if similarity affects shadowing difficulty, pupil dilation should be greatest when the irrelevant message is composed of letters. However, according to Response Selection Theory, which contends that the irrelevant message is processed at a semantic level, the factor which should affect shadowing difficulty is the level of semantic content of the irrelevant message: more shadowing interference should occur with irrelevant messages which have higher degrees of semantic complexity than with those which have lower degrees of semantic complexity. Ambler et al. assumed in their experiment that prose involved more semantic complexity than just words alone and words, in turn, more complexity than either digits or letters.

The results supported the notion that degree of similarity between relevant and irrelevant messages is a factor which determines the difficulty of shadowing. Pupil size was generally highest and decreased the least across serial position when letters comprised the irrelevant message. When either prose, words, or digits constituted the irrelevant message, the decline in pupil size across serial position was quite rapid and did not differ among the three sources of stimulation.

Ambler et al. (1976) designed the final experiment as a replication of the previous experiment by using digits rather than letters as the relevant message. They hypothesized that if relevant-irrelevant message similarity is the factor which influences the rate of decrease in shadowing difficulty, then a minimal rate of decrease would be found when digits comprised the irrelevant message. The results confirmed their expectations: the slowest rate of decrease in pupil dilation over serial position was obtained when relevant and irrelevant messages were both comprised of digits. Furthermore, no differences in rate of decline were found for the other three sources of irrelevant stimulation. In general, then, the results of the Ambler et al. study are inconsistent with Response Selection Theory.

Corteen and Wood (1972) introduced a new methodology for investigating selective attention in providing what they considered to be support for Response Selection Theory. Corteen and Wood first made a semantic category (city names) significant through classical conditioning: subjects monitored a list of words and were given an electrical shock when a city name was presented. These classically conditioned city names, along with unconditioned city names, were embedded in a list of unrelated words to form the irrelevant message. The irrelevant message was presented at a rate of 96 words per minute. Subjects shadowed a passage of prose (i.e., relevant message), which was presented at a rate of 120 words per minute. Corteen and Wood measured the galvanic skin response (GSR) of subjects during the shadowing task and found that conditioned city names resulted in the highest proportion of GSRs. They also found that city names not associated with electrical shocks elicited a higher proportion of GSRs than did control words. However, subjects were unable to post-experimentally report any of the words in the irrelevant message. These results suggested to Corteen and Wood that all of the irrelevant words must have been processed semantically in order for the city names among them to have elicited the GSRs.

A critical question regarding the Corteen and Wood (1972) experiment is whether subjects truly failed to attend to the city names when they were embedded in the irrelevant message. Corteen and Wood had relied on a verbal post-experimental interview to confirm that subjects could not recall the city names presented in the irrelevant message. However, the fact that subjects could not subsequently recall the city names does not eliminate the possibility that the subjects had momentarily attended to the city names during dichotic listening. The subjects may have then failed to store these names in long-term memory due to the interference produced by the shadowing task.

Corteen and Dunn (1974) replicated the experiment by Corteen and Wood (1972) with a modification to control for momentary shifts of attention to the irrelevant message. The modification involved subjects being instructed to stop the shadowing task and press a buzzer if they heard a critical word (i.e., city name) in the irrelevant message. Out of 114 opportunities, on only one occasion did a subject press the buzzer during the experiment. Thus, the results of the experiment by Corteen and Dunn (1974) support the findings of Corteen and Wood (1972).

However, Dawson and Schell (1982) criticized the experimental method used by Corteen and Dunn (1974) to control for the momentary switching of attention to the irrelevant message. They suggested that the instructions by Corteen and Dunn to stop shadowing and press the buzzer if a critical word was detected in the irrelevant message required subjects to terminate the task and acknowledge that they had failed to ignore the irrelevant message. Furthermore, as reported in both of Corteen's studies, subjects shadowed the relevant prose message in phrases with hesitations, rather than continuously. Dawson and Schell suggested that, due to the transitional probabilities of words in the relevant message, attention could have been divided between the two messages without interfering with shadowing accuracy. Based on these observations and research by Wardlaw and Kroll (1976), who reported a failure to replicate the findings of Corteen and his co-workers, Dawson and Schell (1982) designed their experiment to further investigate this supposed phenomenon.

In the Dawson and Schell (1982) experiment, subjects were required to shadow a series of unrelated words rather than a prose passage. They reasoned that this would ensure that subjects would shadow the relevant message, word-for-word, since there would be no contextual cues of what the next word might be. Critical words (animal names or anatomical names) were made significant through classical conditioning, as in the Corteen and Wood (1972) study. These conditioned critical words were then embedded in unrelated words to form the irrelevant message. The messages were presented simultaneously at a rate of one word per .75 seconds. Subjects were required to shadow the relevant message and to ignore the irrelevant one. Three measures were used to indicate when subjects switched attention to the irrelevant message: errors in shadowing performance, a recognition questionnaire completed by the subject after the task, and instructions to press a telegraph key whenever a critical word was detected in the irrelevant message. A measure of electrodermal response (EDR) functioned as the dependent variable.

The results of the Dawson and Schell (1982) study showed that, when the data were analyzed separately for trials in which shifts of attention were known to have occurred (i.e., shift trials) or not occurred (i.e., nonshift trials), significant EDRs were elicited only on shift trials. This result indicates that phasic EDRs are closely associated with attentional shifts to the irrelevant message. Therefore, Dawson and Schell (1982) concluded that the results by Corteen and Dunn (1974) may have been affected by undetected attentional shifts to the irrelevant message.

In review, Deutsch and Deutsch (1963) offered Response Selection Theory to account for evidence which showed that the selective filter (Broadbent, 1958) does allow for analysis of irrelevant stimuli beyond physical characteristics. Thus, Deutsch and Deutsch hypothesized that the attention bottleneck occurs after full analysis of all incoming stimuli. However, some studies have yielded results which indicate that irrelevant stimuli do not always receive full analysis. Treisman (1960) has suggested a model of selective attention which avoids the notion of a bottleneck and, thus, is more flexible than either Filter Theory (Broadbent, 1958) or Response Selection Theory (Deutsch and Deutsch, 1963).

Attenuation Theory (Treisman, 1969)

Treisman (1960, 1964b, 1964c) suggested modifications of Filter Theory to accomodate the growing evidence against the notion that a filter selectively excludes information at an early stage of processing. Treisman (1960) found that subjects usually repeated one or two words from the irrelevant message in a shadowing task when the relevant and irrelevant messages were switched to the other ear. In order to account for these results and the findings of Moray (1959) that "important" messages, such as one's own name, could penetrate the selective filter, Treisman suggested that hypothetical "dictionary units" (i.e., store of known words) in memory are activated by sensory messages. Each unit has a specific threshold which must be surpassed for perception to occur. Some of the units are permanently more available for activation as their thresholds are permanently lower (e.g., a person's own name and danger signals, such as "watch out" or "fire"). The threshold for a unit can also be lowered temporarily when another unit, which is either in the appropriate context of or transitionally related to the first unit, is activated. For example, if the words "I sang a" were heard, the stored trace of the word "song" in the dictionary would have a temporarily lowered threshold.

Treisman (1960) further suggested that the selective mechanism in attention may be thought of as "attenuating," rather than "blocking," the irrelevant message. Signals of all stimuli would therefore be delivered to the dictionary by the senses; however, some of the signals would be attenuated and not result in the appropriate dictionary unit being activated. Thus, if a subject had instructions to shadow a message presented to one ear, stimuli delivered to the other ear would generate a weaker signal when applied to the dictionary.

In an attempt to investigate selective attention when identification of verbal or linguistic features, but not spatial localization, could be used as cues, Treisman (1964c) used a shadowing task which involved binaural presentation of prose in known and unknown languages. Both relevant and irrelevant messages were recorded at a rate of 150 words per minute. In Part I of the experiment, the messages to be shadowed were recorded in a female voice and consisted of narrative or descriptive excerpts from the novel Lord Jim by Conrad. The irrelevant messages were

> (1) English prose from the same novel, in a man's voice; (2) English prose with a long interpolated passage of Latin, in a man's voice; (3) English prose from the same novel, in the same woman's voice as the shadowed message; (4) English prose from a technical discussion of biochemistry, in the same voice; (5) French prose from a novel, in the same voice; (6) German prose from a novel, in the same voice; (7) Italian prose from a novel, in the same voice; (8) Czech, simplified and spoken with a deliberately English accent (equivalent to nonsense using the same phonemes as English), in the same voice; (9) English played backwards, in the same voice, and (10) A French translation of the English shadowed message, in the same voice (p. 208).

Many of the subjects were studying modern languages at Oxford University. All subjects were rated on their knowledge of French, German, and Italian accordingly: A (bilingual or fluent), B (some knowledge of the language), and C (no knowledge). Hence, each subject received three ratings, one for each of the three languages.

Since the experimental lists were presented binaurally, a delay was introduced between the onsets of the two lists to fascilitate the beginning of shadowing. Subjects were asked to repeat the message which started first (i.e., the excerpts from Lord Jim). Additionally, subjects were encouraged not to refrain from shadowing when unsure of which message was the relevant one, but to repeat as much as possible of the message they believed to be correct. The responses were then analyzed for percentage of words correctly repeated, intrusions from the irrelevant message, errors, and omissions. At the end of the experiment all subjects were asked if they had noticed the content of the irrelevant message.

The results showed that performance was better when the irrelevant message was in a different voice than that of the relevant message, regardless of the type of language spoken in the irrelevant message. Treisman also found that,when both messages were in the same voice and equally intelligible (conditions 4, A5, A6 and A7), there was no difference in performance. However, when the irrelevant message was also from the Lord Jim (condition 3), there was both a decrease in the number of words correctly repeated and an increase in the number of intrusions than when the irrelevant message consisted of the technical discussion of biochemistry (condition 4). Treisman concluded that "the important factor with messages in the same voice seems to be not a language-difference, as such, but the presence of a cue to distinguish the two messages; two passages taken from the same novel would have much more in common than a passage from a novel and a passage of technical biochemistry" (p. 212).

The effect of semantic content was shown more clearly in the results of Part II of Treisman's (1964c) experiment.

The messages to be shadowed consisted of 1st, 2nd, 4th, 6th, 8th, and 12th order statistical approximations to English (Miller and Selfridge, 1950). Each message was 100 words long and lasted 40 seconds. The irrelevant message was recorded in the same voice as the relevant message and consisted of excerpts from Lord Jim. Subjects were instructed to shadow the message which began first (i.e., the statistical approximation to English) and to ignore the other message. The number of words correctly repeated and the number of intrusions from the irrelevant passage were both recorded.

The results showed that, beginning with the 12th order statistical approximation and proceeding to the 1st order, there was a consistent decrease in the number of words correctly repeated along with a concurrent increase in the number of intrusions from the irrelevant message. The total number of words repeated remained almost constant, as the increase in intrusions compensated almost exactly for the decrease in words correctly repeated from the relevant message. Therefore, the the prose excerpts from Lord Jim progressively became more likely to disrupt shadowing as the relevant message became less contextually constrained.

In order to account for these results, Treisman (1964b, 1964c) postulated that an analytical mechanism performs a series of tests on incoming stimuli. The first tests distinguish among the stimuli on the basis of physical cues (e.g., different voices), whereas later tests distinguish among stimuli on the basis of semantic cues (e.g., different meanings). The tests can be represented as a branching tree or "hierarchy" whose terminals are particular dictionary units. According to Treisman (1964c), each test may be considered as a "signal detection problem" in which a certain adjustable criterion point is adopted on the dimension being discriminated. Signals above the criterion point are accepted and further analyzed, whereas signals below the criterion point are rejected as noise. The criteria determining the results of the tests may be lowered for particular outcomes by contextual probabilities or importance. The result of each test causes the signal of the stimuli to be passed down one of several alternative paths until the appropriate series of tests has been completed to distinguish one message from the other. Therefore, the irrelevant message which is attenuated would "pass the tests only if the criteria had been lowered in their favor and, if not, would pass no further through the hierarchy" (1964b, p. 14).

Treisman and Geffen (1967) attempted to identify whether selective attention operates primarily on perception or on response. The experimental procedure required subjects to shadow all items arriving on a designated ear (i.e., relevant message) while performing an additional task (tapping) when target items were heard, regardless of the ear of origin. Relevant and irrelevant messages were presented dichotically and consisted of excerpts from <u>Lord Jim</u> by Conrad. Both messages were recorded in a female voice. Target items consisted of both unrelated words and either digits, colors, or parts of the face. Target words were embedded within both messages with the restriction that none occurred in the first or last ten words or within less than eight words of another target word in either the same message or the message presented to the other ear. Both relevant and irrelevant messages were 150 words long and lasted about one minute. According to Response Selection Theory, a target item should elicit a tapping response regardless of the ear of origin because the corresponding recognition structure is preset. Filter Theory, on the other hand, would predict that none of the target items in the irrelevant message should elicit a tapping response. Attenuation Theory, however, proposes that the requirement to shadow the relevant message restricts, but does not preclude, processing of items in the irrelevant message. Therefore, Attenuation Theory predicts that some, but not all, target items in the irrelevant message should elicit a tapping response. The results supported Attenuation Theory as subjects detected 87 percent of the target words in the relevant message but only 8 percent in the irrelevant message.

Deutsch and Deutsch (1967) did not hold the results by

Treisman and Geffen (1967) to be critical. They suggested that Treisman and Geffen may have produced a situation in which target items in the relevant message were given a larger weighting of importance than target items in the irrelevant message. They argued that this bias may have occurred due to the fact that subjects were instructed to tap and repeat one set of words and only to tap in response to the other set of words.

Treisman and Riley (1969) performed an experiment in response to Deutsch and Deutsch's (1967) criticism. The major difference between the Treisman and Riley experiment and the Treisman and Geffen experiment was the instruction to stop shadowing immediately and to tap upon detection of a target item (i.e., letter) in either message. Therefore, the response to a target was identical regardless of the message in which the target appeared. One letter was embedded in both the relevant and irrelevant messages, which consisted of digits. The relevant and irrelevant messages were presented simultaneously at a rate of one digit per .6 seconds. Subjects detected 76 percent of the target items which appeared in the relevant message but still only detected 33 percent of the target items which appeared in the irrelevant meessage. Thus, while Deutsch and Deutsch (1967) were somewhat correct in their criticism of Treisman and Geffen's (1967) methodology, the results of Treisman and Riley (1969) stand as support for Attenuation Theory.

In review, Treisman (1969) has suggested an attenuation model which explains the limitations of selective attention as being due to a hierarchy of tests, rather than a structural bottleneck, which cause suppression of irrelevant stimuli. The degree of suppression is dependent upon how early in the hierarchy tests are able to distinguish differences between stimuli. Several studies have shown results which support Attenuation Theory. However, Attenuation Theory does not specify the relationship between attention devoted to one task and the amount of suppression imposed on irrelevant stimulation. A theory which does address this issue is Kahneman's (1973) Capacity Theory.

<u>Capacity Theory (Kahneman, 1973)</u>

Kahneman (1973) suggested Capacity Theory to compensate for some of the shortcomings of earlier theories of attention. Capacity is viewed as a dynamic pool of resources that is available for the processing of information. The amount of capacity is assumed to vary with the overall level of arousal: more capacity is available when arousal is moderately high than when arousal is relatively low. Regardless of the amount of capacity available at any point in time, some degree of flexibility exists in allocating effort (i.e., capacity) to the performance of mental tasks. According to Kahneman, the allocation of effort is controlled by four factors:

> 1. Enduring dispositions which reflect the rules of involuntary attention (e.g., allocate capacity to any novel signal; to any object in sudden motion; to any conversation in which one's own name is mentioned);
> 2. Momentary intentions (e.g., listen to the voice on the right earphone; look for a redheaded man with a scar);
> 3. The evaluation of demands: there appears to be a rule that when two activities demand more capacity than is available, one is completed;
> 4. Effects of arousal (p. 11).

Kahneman asserts that the effort invested in a task is determined mainly by the intrinsic demands of the task, whereas voluntary control over effort is quite limited. When the demands of a task do not exceed the available capacity, errorless performance can result. In fact, the "spare capacity" can be used to perform additional tasks. However, according to Kahneman, the primary use of spare capacity is to monitor a person's surroundings. Thus, as the effort invested in a task increases, spare capacity decreases. In other words, attention is withdrawn from perceptual monitoring and concentrated on the task at hand.

When the supply of capacity does not meet the demands of a task, performance either falters or fails completely. According to Kahneman (1973), "an activity can fail, either because there is altogether not enough capacity to meet its demands or because the allocation policy channels available capacity to other activities" (p. 9). An action can also fail because the input of relevant information is insufficient. Therefore, if a word is spoken very faintly, no amount of attention can make the word intelligible.

In contrasting Capacity Theory with structural models of selective attention, Kahneman contends that the two approaches are of different types. Structural models describe a sequence of operations that are applied to a set of simultaneously presented stimuli and maintain that interference occurs when the same mechanism is required to conduct two incompatible operations at the same time. Capacity Theory, on the other hand, describes the relations of influence and control between components of a system and postulates that interference occurs when the demands of two activities exceed available capacity.

Another advantage of Capacity Theory derives from a comparison with Attenuation Theory. While Attenuation Theory indicates that irrelevant stimulation can be suppressed, the relationship between attention devoted to one task and the amount of suppression imposed on the irrelevant stimulation is not specified. Capacity Theory, on the other hand, not only elucidates this relationship but also specifies factors that control the allocation of effort.

The proposal by Kahneman (1973) that effort invested in a task is mainly determined by intrinsic demands of the task was suggested by experimental results from Kahneman, Peavler, and Onuska (1968). Kahneman et al. (1968) required subjects to separately perform easy and relatively difficult tasks under varying conditions of **monetary** incentive and risk. The tasks involved either adding one (difficult task) or adding zero (easy task) to each member of a series of numbers. Subjects were either rewarded or penalized for performance in the amount of ten cents (high-incentive trials) or two cents (low-incentive trials). Pupil diameter was used as the measure of effort expended on the task and was recorded for all conditions. Kahneman et al. found that pupil size for the difficult task was higher than for the easy task when no incentives were offered for correct performance. They also found that incentive had no effect on pupil size during the difficult task and had only a minimal effect of pupil size during the easy task. These results suggested to Kahneman et al. that the major determinant of effort is the difficulty of the task.

Another study upon which Capacity Theory was based was Zelnicker (1971). Three pairs of two-digit numbers were presented to one ear at a rate of two two-digit numbers per second. The non-selective attention (NSA) condition required subjects to repeat the first pair of two-digit numbers twice, coinciding with the presentation of the second and third pair of two-digit numbers. The selective attention (SA) condition required subjects to repeat the first pair of two-digit numbers while hearing the second pair and to repeat the second pair while hearing the third pair. In both conditions (NSA and SA), the irrelevant message consisted of the subject's responses, which were recorded and then delayed .2 seconds before being presented to the other ear. Sucn delayed auditory feedback (DAF) often causes stuttering. Thus, Zelnicker used stuttering frequency resulting from DAF as a measure of the difficulty cf the task.

The results indicated that less stuttering occurred in the SA condition than in the NSA condition. Kahneman (1973) argued that these results were consistent with Capacity Theory. The more demanding task (SA) resulted in less spare capacity being available to perceptually monitor the DAF. Since there was not a sufficient amount of spare capacity to meet the demands of the DAF to be monitored for words and meaning, the irrelevant message was effectively ignored. On the other hand, because the demands of the NSA condition were less than the demands of the SA condition, more spare capacity was available to be captured by the DAF, which resulted in more interference.

Support for Capacity Theory over Response Selection Theory was shown by Bookbinder and Osman (1979). Bookbinder and Osman presented dichotic lists of unrelated words at a rate of one word per .6 seconds. Subjects responded by button-pressing to color words interspersed in the relevant message. Subjects were also to detect a non-color target word, which was presented in either the relevant or the irrelevant message, by saying aloud "now" when the target was heard. The target word in the irrelevant message never appeared opposite a color word in the relevant message. Subjects were told that button-pressing to color words was the main task and that they should be as accurate as possible. Subjects were also instructed to stop the button-pressing task after they had detected the target word. Bookbinder and Osman maintained that equal target-detection performance for relevant and irrelevant messages would not be at all unlikely, but a failure to obtain such a result would be clearly inconsistent with Response Selection Theory.

Target detection in the relevant message was approximately 80 percent. However, less than 40 percent of the target words were detected in the irrelevant message. Thus, results yielded by the Bookbinder and Osman (1979) study are inconsistent with Response Selection Theory, since targets in the irrelevant messages apparently were not fully perceived. Bookbinder and Osman also found that subjects who performed better in the button-pressing task performed worse in the target-detection task and vice versa. All subjects who achieved performance above the mean (81.6%) in the button-pressing task detected fewer than the mean number (3.75) of detected targets. The reverse finding held for all subjects who performed below the mean on the button-pressing task. Bookbinder and Osman interpreted this reciprocal relationship between button pressing and target detection in terms of Capacity Theory as follows: The amount of effort allocated to focus on detection of color words in the relevant message determined the amount of spare capacity allocated to target detection.

In review, Kahneman (1973) has proposed Capacity Theory as an alternative to both structural theories of attention and Attenuation Theory. Capacity Theory assumes that the intrinsic demands of the primary task determine both the amount of effort allocated to that task and the amount of spare capacity available for perceptual monitoring. Studies have been presented which support Capacity Theory over structural models of selective attention. However, no evidence exists which favors Capacity Theory over Attenuation Theory.

Summary

The models of selective attention proposed by Broadbent (1958), Deutsch and Deutsch (1963), and Treisman (1964c) suggest that there are different levels of perceptual analysis for determining the meaning of irrelevant stimuli. Broadbent (1958) suggested that a "filter" sorts stimuli by physical characteristics (e.g., voice quality, location of sound) and allows perceptual analysis only for relevant stimuli. Deutsch and Deutsch (1963) proposed that all stimuli reach full perceptual analysis and that the limits of attention apply only to awareness, memory, and response. Treisman (1964c, 1969) postulated that a hierarchy of tests is utilized to perform an analysis on stimuli. Stimuli are first assessed for physical features and then checked for semantic properties. Irrelevant stimuli are "attenuated" as tests in the hierarchy are failed.

Kahneman (1973) suggested that selective attention is dependent upon the capacity or "mental effort" available to conduct certain tasks. Interference occurs when the demands of two activities exceed available capacity. Kahneman argues that in a structural model interference between tasks is "specific" and depends on the degree to which the tasks call for the same mechanisms. In Capacity Theory, interference is "nonspecific" and depends on the demand requirements of both tasks.

Statement of Problem

One variable which has not been investigated systematically in the context of selective attention concerns the organization of stimulus information. The beneficial effects of categorized material over uncategorized material on memory have been well documented (see Klatzky, 1980). The issue remains, however, as to whether or not similar effects occur for attention processes. Thus, the purpose of this thesis is twofold: to investigate the effects of categorized versus uncategorized material on selective attention and to test predictions derived from Filter Theory (Broadbent, 1958), Response Selection Theory (Deutsch and Deutsch, 1963), and Attenuation Theory (Treisman, 1969).

Such an investigation requires an extension of the work by Ambler, Fisicaro, and Proctor (1976). To reiterate, Ambler et al. found that pupil size was generally highest and decreased the least across serial position when relevant and irrelevant messages came from the same category. However, when the irrelevant message was either uncategorized or a different category than the relevant message, the decline in pupil size across serial position was quite rapid. Note, though, that Ambler et al. used only categorized lists for the relevant message while using both categorized and uncategorized lists for irrelevant messages. The author's experiment will utilize the following modifications of the Ambler et al. study: First, both categorized (C) and uncategorized (U) lists will be used for both relevant and irrelevant messages. Thus, four experimental conditions will be generated: U-U, U-C, C-U, and C-C. Note that the left-most symbol designates the relevant message and the right-most symbol designates the irrelevant message. Second, no category list will be used more than once for either relevant or irrelevant messages.

The models of selective attention proposed by Broadbent (1958), Deutsch and Deutsch (1963), and Treisman (1969) predict different results of the author's experiment. Broadbent (1958) contended that the irrelevant message is filtered out solely on the basis of physical features (e.g., localization of sound, pitch). Specifically, since the irrelevant message will be presented to only one ear, sound localization cues should allow the filter to effectively block the irrelevant message, regardless of content. Filter Theory would therefore predict no decrease in pupil size across serial position in any condition. Futhermore, since no provision exists in Filter Theory for potential effects of categorized versus uncategorized material, Filter Theory must predict no difference in pupil size across the four conditions. Finally, based on the previous two predictions, Filter Theory would also predict no interaction between condition and serial position.

Response Selection Theory, on the other hand, would appear to make a different set of predictions for the outcome of the author's experiment. Deutsch and Deutsch (1963) proposed that all simultaneously presented stimuli reach full perceptual analysis. They further stated that the weighting of importance associated with a central structure may reflect momentary intentions (e.g., words related to animal names are now important) and therefore increase the likelihood of that structure being recognized as relevant or irrelevant. In general, then, as more use can be made of momentary intentions to identify relevant and irrelevant messages, shadowing should become easier. Thus, pupil size should be greatest in the U-U condition across serial position because momentary intentions cannot be used as a basis for separating relevant and irrelevant messages. On the other hand, pupil size for the C-C condition should be smallest across serial position as differentiation of relevance and irrelevance would be strongly enhanced by the use of momentary intentions. Presentation of the U-C condition should result in pupil size being less than in the U-U condition but greater than in the C-C condition across serial position. This would occur due to the irrelevant message in the U-C condition being recognized through the aid of momentary intentions. For similar reasons, presentation of the C-U condition should result in pupil size being approximately the same as in the U-C condition. Furthermore, since time would be required to recognize words in the categorized lists as being related and important, an interaction between condition and serial position should occur: initially pupil size should be the same for all conditions but should decrease differentially across serial position as categorized lists are recognized as such.

Treisman, Squire, and Green (1974) would contend that time is required to focus attention on the relevant message. Therefore, pupil size should decrease across serial position in each condition. However, Treisman (1969) would further argue that the rates of decline should be different for the different conditions. The cause of this interaction between condition and serial position would be due to the ease with which tests in the hierarchy were able to separate the two messages on some dimension (e.g., localization of sound, content). The U-U condition should result in pupil size being the largest across serial position since the irrelevant stimuli would fail only the tests for localization of sound and volume. Likewise, the C-C condition should result in pupil size being the smallest because the irrelevant stimuli would fail tests mentioned in the U-U condition and be further attenuated by failing the test for semantic content. The decrease in pupil size caused in U-C and C-U would fall between and be different from U-U and C-C as only the categorized messages and localization cues would aid in attentuation of the irrelevant message. Thus, Treisman would predict essentially the same results as Deutsch and Deutsch (1963).

Although Kahneman has proposed an alternative to Filter Theory, Response Selection Theory, and Attenuation Theory, an experimental investigation of Capacity Theory is beyond the focus of the author's study. In fact, Allport (1980) raises serious doubts as to the testability of Capacity Theory in general.

METHOD

Subjects

Thirty-two student volunteers from undergraduate and graduate psychology classes at Western Kentucky University served as subjects. All were normal with respect to hearing (determined by self-report from the subject) and were naive with respect to dichotic-listening tasks and the literature on selective attention.

Materials and Conditions

Sixteen lists of one-syllable nouns (16 words per list) were used to form the experimental conditions. These lists were constructed from the Battig and Montague (1969) norms, which provide frequencies with which words are given in response to category names. Words were selected from eight of the Battig and Montague categories which would provide similar mean word frequencies for each categorized list. These words were then randomly assigned to serial position to form the eight categorized lists. The categories used were tools, transportation, birds, body parts, animals, kitchen utensils, weather, and clothes. Eight uncategorized lists were then constructed by selecting words from categories other than those mentioned above which would produce lists with mean word frequencies similar to those for the categorized lists. No two words in any uncategorized list came from the same category listed in Battig and Montague. Lists were then matched according to similar mean word frequencies to form two pairs of lists for each of four conditions: U-U, U-C, C-U, C-C. Note that the left-most symbol designates the relevant message and the right-most symbol designates the irrelevant message. No word appeared in more than one list or more than once within the same list.

Twelve lists of one-syllable nouns (16 words per list) were then constructed for practice trials. Four lists were used for shadow practice only, as no irrelevant message was included. The remaining eight lists were paired to form four dichotic-practice trials. The shadow-practice lists are presented in Appendix A, and the dichotic-practice lists are displayed in Appendix B.

Two different orderings of the experimental-dichotic trials were employed. Half of the subjects received the conditions in the following order: U-U, C-U, C-C, U-C, C-U, U-U, U-C, C-C. The other half of the subjects received the conditions in the following order: U-C, C-C, U-U, C-U, C-C, U-C, C-U, U-U. The two orders were generated as follows. The four conditions were randomly ordered twice. These two orderings were used to form the first halves of the two orderings just presented (U-U, C-U, C-C, U-C and U-C, C-C, U-U, C-U, respectively). The second halves of the two orderings were constructed by placing conditions in sequence (C-U, U-U, U-C, C-C and C-C, U-C, C-U, U-U, respectively) such that the mean position of each condition across the two orderings would be 4.5. For example, the U-U condition appears in positions 1 and 6 in the first ordering and in positions 3 and 8 in the second ordering for a mean position of 4.5. The words lists that comprised the experimental conditions, along with specific word frequencies, are presented in Appendix C.

All word lists were recorded in the same male voice at a rate of one word per second. A word pair was accepted as being simultaneous if no obvious onset asynchrony was readily apparent upon listening to the tape and observing the volume unit (VU) meter on the tape recorder. The intertrial interval (ITI) between lists was 13 seconds. The average intensity, referenced to sound pressure level (SPL), was 73.7 (+2)dB for relevant messages and 70.5 (+2)dB for irrelevant messages.

Apparatus

Word lists were played to subjects on a Technics (Model 641) stereo cassette recorder. The outputs of the recorder were passed through a Lafayette (Model LA-125B) amplifier to an external speaker and Koss (Model K-6) stereo headphones. While subjects listened to the word lists, which were presented dichotically over the headphones, the experimenter monitored the stimulus tape from the output of the external speaker. Only the relevant (i.e., shadowed) message was played through the external speaker.

The subject sat in a chair in front of which was positioned a chin and forehead rest. The subject was able to respond verbally without changing eye position by pressing against the forehead rest. Pupil size was continuously monitored and recorded for each subject via a Technicolor (Model 412D) video camera connected to a Technicolor (Model 335T) video recorder. The video camera lens was covered by a sheet of white paper (21.6 cm by 27.9 cm) except for a small circular hole (19 mm in diameter) in the center. With the use of a 20-mm extension tube, the camera lens was situated directly in front of the subject's right eye (3.8 cm away). This arrangement effectively eliminated extraneous distractions and reflections of the camera lens on the subject's eye and resulted in a 14.5X enlargement of the pupil on the video monitor. A microphone was placed in front of the external speaker and connected to the video tape recorder so that the relevant message and pupil dilations could be recorded simultaneously.

Procedure

Each subject was given a brief description of the apparatus and told that the task was to shadow (i.e., repeat immediately) words presented to a designated ear.

Subjects were first given the four shadow-practice trials. They were then given the four dichotic-practice trials in which they were instructed to shadow the words presented to one ear and ignore the words presented to the other ear. Although pupil dilations were not recorded during any of the practice trials, subjects were positioned as if they were being videotaped. Videotaping began with presentation of the eight experimental dichotic trials. Each relevant message was preceeded by "one, two, three" to facilitate the beginning of shadowing. Half of the subjects received relevant messages in the left ear while the rest received them in the right ear. All subjects were instructed to shadow the relevant message and ignore the irrelevant message. None of the subjects were given any information about the content of any lists.

Measurement of Shadowing Errors

Shadowing errors (i.e., omissions of relevant words, mispronunciations of relevant words, or intrusions of irrelevant words) were recorded during the experimental session while subjects were shadowing the relevant message. Errors were then scored separately within quadrants of the relevant message. The first quadrant consisted of the first through fourth words, the second quadrant consisted of the fifth through eighth words, and so on. The error score for each quadrant was then converted to a percent separately for each condition.

Measurement of Pupil Dilation

The videotape, containing both an auditory recording of the stimuli shadowed by the subject and a visual recording of pupil dilations, was played back after the experimental session. Two experimenters were present whenever measurements of pupil size were taken. One experimenter controlled the playback of the videotape. The other experimenter consulted the response sheet, which indicated both correct and incorrect shadow responses, and recorded the data. Measurements of pupil size were made via a calibrated transparent grid placed over the video monitor. The experimenter who made judgments regarding pupil size was naive to the purpose of the experiment.

Data were collected from the eight experimental-dichotic trials. In order to obtain a respresentative sample of pupil size measurements across serial position without introducing unnecessary redundancy, trial measures were taken at the 1st, 4th, 7th, 10th, 13th, and 16th positions in each list. Additionally, in order to obtain a reliable and stable measurement of pupil size when effort was not being invested in the shadowing task, two baseline measures were taken during the 13-sec ITI at 9 seconds and 5 seconds before the presentation of the lists. Since each subject received eight experimental trials (two trials in each of four conditions), there were four baseline measures per condition. In each condition the four baseline measures were averaged and the two trial measures were averaged separately at each of the six positions. The mean baseline was subtracted from each of the six position means in each condition. These mean difference scores were used in the analysis.

Design

A 4 by 4 ANOVA with repeated measures on both factors was used to analyze shadowing errors. The first factor consisted of the four conditions: U-U, U-C, C-U, and C-C. The second factor consisted of the four quadrants of measurement.

A 4 by 6 ANOVA with repeated measures on both factors was used to analyze pupil measurements. The first factor consisted of the four conditions: U-U, U-C, C-U, and C-C. The second factor consisted of the six positions of measurements.

RESULTS

Mean difference from baseline in pupil size across subjects is presented as a function of Condition and Serial Position in Figure 1. The main effect of Condition was not significant, $F(3,93)=1.09$, $p>.05$, $MSe=.231$. The analysis demonstrated a significant effect of Position, $F(5,155)=30.02$, $p<.05$, $MSe=.034$, with pupil size decreasing over time. However, there was not a significant Condition by Position interaction, $F(15,465)=1.01$, $p>.05$, $MSe=.024$. The lack of an interaction indicates that the curves corresponding to the four conditions did not differ in the manner in which they decreased across serial position.

Mean error rate across subjects is presented as a function of Condition and Quadrant in Figure 2. The main effect of Condition was not significant, $F(3,93)=1.44$, $p>.05$, $MSe=107.07$. The main effect of Quadrant was also not significant, $F(3,93)=2.57$, $p>.05$, $MSe=114.32$. However, the Condition by Quadrant interaction was significant, $F(9,279)=2.10$, $p<.05$, $MSe=85.79$. This result indicates differential effects of condition as a function of quadrant of measurement.

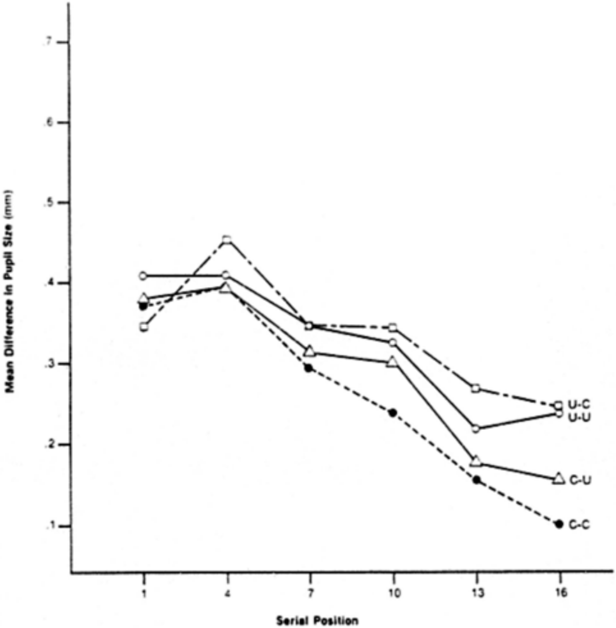

Figure 1. Mean difference from baseline in pupil size as a function of condition and serial position.

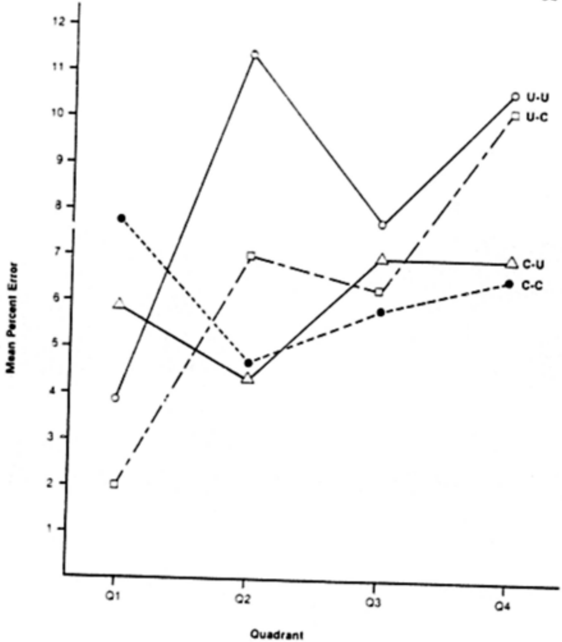

Figure 2. Mean percent error as a function of condition and quadrant.

An analysis of the interaction was performed by partitioning the sum-of-squares into three components. The first component, which compared the U-U curve to the U-C curve, was not significant, $F(3,279)<1.00$, $p>.05$, $MSe=85.79$. The second component, which compared the C-U curve to the C-C curve, was not significant, $F(3,279)<1.00$, $p>.05$, $MSe=85.79$. However, the third component, which compared the U-U and U-C curves to the C-U and C-C curves, was significant, $F(3,279)=5.5$, $p<.05$, $MSe=85.79$. This indicates that shadowing errors increased more over time when the relevant message consisted of uncategorized words rather than categorized words.

DISCUSSION

Based on the finding of a significant main effect of position and visual inspection of Figure 1, the analysis of pupil size suggests that the amount of effort invested to perform the shadowing task decreased as serial position increased. This finding replicates results of the Ambler et al. (1976) study and is consistent with the notion that time is required to focus attention on the relevant message (Treisman et al., 1974). The lack of a main effect of condition might suggest no differences in shadowing difficulty for the four conditions. However, the implications drawn from the results of the pupil size analysis must be considered in light of the error rate data.

In order for pupil size to provide an accurate account of the effort invested to shadow words in each condition, error rate must be similar for all conditions. This insures that the necessary effort is being invested to successfully perform the task, regardless of the degree of task difficulty. As Kahneman (1973) has proposed, when effort is not properly allocated to meet the demands of a task, performance either falters or fails completely. Evidently, the situation described by Kahneman occurred in the author's experiment. Thus, since the analysis of pupil size produced no evidence that the amount of effort invested in the shadowing task differed for the four conditions, the error rate data should reflect the degree of shadowing difficulty and must be used in lieu of the pupil dilation data for further discussion.

The results of the error rate analysis and visual inspection of Figure 2 suggest that shadowing difficulty increased when the relevant message consisted of uncategorized words but remained relatively constant across serial position when the relevant message consisted of categorized words. In other words, the effort invested in the U-U and U-C conditions did not adequately meet the demands of the task to allow shadowing performance similar to the C-U and C-C conditions. If effort had been invested to shadow the U-U and U-C conditions as accurately as the C-U and C-C conditions, then pupil size probably would have been larger for the U-U and U-C conditions across serial position. However, one cannot ascertain how much larger.

In general, the results of the author's study support and extend the results obtained by Ambler et al. (1976). As in the Ambler et al. study, no difference was found between conditions when the relevant message consisted of categorized words and the irrelevant message consisted of either uncategorized words or a category different than that of the relevant message. In extending the results of

Ambler et al., no differences in shadowing difficulty occurred when the relevant message consisted of uncategorized words and the irrelevant message consisted of either uncategorized or categorized words. Furthermore, the nature of the obtained interaction between condition and quadrant indicates that shadowing difficulty was dependent upon the content of the relevant message (categorized material versus uncategorized material). This last result constitutes the major finding of the author's experiment and will be used as the primary basis for evaluating Filter Theory, Response Selection Theory, and Attenuation Theory.

In short, Filter Theory is unable to account for the obtained interaction between condition and quadrant. The reasoning is as follows: If a "filter" was operating to block the irrelevant message, then error rate should not have increased across quadrants more in the U-U and U-C conditions than in the C-U and C-C conditions.

In terms of evaluating Response Selection Theory, the results of the error rate analysis must be considered as tentative. The findings of no effect of type of irrelevant message on shadowing errors is contrary to Response Selection Theory. In other words, the presentation of categorized words in the irrelevant message appears not to have caused the corresponding central structures to be recognized any easier as being different from the relevant message than when the irrelevant message consisted of uncategorized words. This casts doubt on the proposal by Response Selection Theory that the irrelevant message reaches full perceptual analysis. However, the fact remains that this argument is based on a non-significant effect and should be accorded all caveats typically associated with such results.

A similar situation holds for Attenuation Theory. The lack of an effect of type of irrelevant message suggests that tests in the hierarchy were not aided by content of the irrelevant message. The fact that the contextual probabilities were higher when the irrelevant message consisted of categorized material rather than uncategorized material appears not to have influenced the amount of attenuation of the irrelevant message. Supporters of Attentuation Theory could argue that the irrelevant message was attenuated at an early stage of analysis due to physical cues. However, this arguement would suggest a prediction similar to that of Filter Theory which, as explained earlier, is not supported.

Given the fact that pupil size was unaffected by the experimental conditions, the author suggests that a further study be conducted to clarify the results obtained in this thesis. As indicated earlier, in order for pupil size to reflect the amount of effort invested in the shadowing task, error rate must remain relatively constant and low across experimental conditions. Two possible ways of lowering error rate would be to emphasize the importance of errorless shadowing and/or to reduce the intensity of the irrelevant message. However, if the intensity of the irrelevant message is too low, shadowing may be so easy as to result in a basal effect for all conditions.

APPENDIX A

Shadow-Practice Lists

Watch	Plug	North	Trap
Sax	Ring	Life	End
Room	Earth	Fact	Act
Stage	Wig	Gas	Pond
Race	East	Pitch	Mass
Bill	Stick	Hood	Shoe
Whip	Edge	Pit	Date
Trunk	Match	Rose	Milk
Red	Plum	Stripe	Art
Slope	Stand	Jag	Faith
Board	Hook	Sea	Pie
Vase	Fame	Mess	Ton
Mark	Jail	Fence	Field
Sword	Hump	Mask	Mob
Phone	Sash	Base	South
Lake	Elf	Light	Fan

APPENDIX B

Dichotic-Practice Lists

U	- U	U	- U
Beach	Page	Fast	Leaf
Queen	Cure	Man	Pike
Rail	Volt	Raid	Noise
Tea	Zoo	Lime	Book
Bluff	State	Pad	Square
Tack	Clay	Brake	Tag
Damp	Boss	Tar	Wave
Test	Junk	Box	Lamp
Look	Cream	Guilt	Math
Breath	Work	Chart	Fine
Squirt	Gray	Bag	Rank
Chain	Fire	Meat	Cliff
Rest	Joint	Fate	Band
Park	Ray	Creek	Dream
Coke	Lance	Brand	Lens
Line	Boss	Grape	Spike

Dichotic-Practice Lists (cont.)

U	U	U	U
Can	Blood	Tip	Palm
Pear	West	Word	Shock
Sage	Bomb	Bronze	Dart
Knot	Hymn	Latch	Egg
Teak	Air	Hill	Quart
Rust	Bow	Peach	Flag
Land	Start	Kid	Gorge
Blonde	Hurt	Quilt	Length
King	Farm	Jazz	Wind
Key	Ink	Cent	Lead
War	Jug	Script	Grain
Lace	Pin	Tent	Home
Dill	Club	Grade	Dust
Beige	Gulf	Hitch	Week
Sir	Drum	Spear	Brown
Deck	Rage	Couch	Step

APPENDIX C

Experimental Lists and Word Frequencies

U	-	U		U	-	U	
Check	45	March	16	Block	98	Pool	14
Dance	14	Sign	8	Chess	9	Dean	2
Stone	20	Brace	3	Rope	16	Song	10
Judge	18	Clap	1	Cop	2	Tan	42
Fern	9	Swing	16	Mood	10	Pipe	13
Hop	4	Game	106	Doll	285	Wing	14
Dorm	63	Chief	4	Night	6	Prose	4
Pink	224	Fat	1	Gold	56	Day	404
Chimes	3	Seat	2	Theme	6	Porch	16
Punch	45	Horn	51	Hutch	7	Mill	4
Sprite	19	Dime	261	Bar	6	Sin	3
Rug	51	Lock	2	Stream	44	Crib	3
Plains	68	Couch	168	Cleat	13	Fig	9
Card	12	Mint	1	Hate	1	Pump	15
Play	31	Slop	13	Fist	46	Cave	69
Shake	28	Wax	2	Nurse	47	Tank	31
$\overline{X} = 40.88$		$\overline{X} = 40.94$		$\overline{X} = 40.75$		$\overline{X} = 40.81$	
$S = 52.89$		$S = 74.9$		$S = 70.44$		$S = 98.43$	

Experimental Lists (cont.)

U		C		U		C	
Score	46	Cup	49	Fair	4	Vest	29
Lake	98	Sink	31	Twist	244	Suit	53
Cook	8	Lid	7	Steam	20	Cape	2
Yen	66	Dish	42	Moon	3	Hat	201
Lust	2	Stove	74	Folk	138	Glove	99
Swim	35	Grill	4	Cast	2	Hose	16
Tap	14	Sieve	8	Ridge	18	Belt	84
Jade	84	Pot	205	Fraud	21	Cap	9
King	3	Sponge	6	Clove	94	Smock	1
Bay	7	Mold	1	Hit	1	Bra	70
Flue	48	Brush	1	Note	12	Scarf	64
Waltz	31	Jar	4	Bond	12	Robe	7
Joke	2	Glass	27	Fast	13	Shorts	71
Track	111	Bowl	69	Coin	94	Boot	8
Sauce	14	Tongs	9	Sky	45	Gown	1
Tab	5	Plate	34	Chef	2	Jeans	2
$\overline{X} = 35.88$		$\overline{X} = 35.69$		$\overline{X} = 45.19$		$\overline{X} = 44.81$	
$S = 36.42$		$S = 51.09$		$S = 66.96$		$S = 53.71$	

Experimental Lists (cont.)

C	-	U		C	-	U	
Gull	5	Jerk	107	Wrench	61	Thief	4
Lark	15	Soul	2	Saw	394	Juice	48
Owl	36	Teem	23	Clamp	1	Law	1
Thrush	31	Hay	1	Axe	14	Swamp	2
Dove	36	Steal	95	Wedge	15	Pop	21
Crow	149	Fir	60	Bolt	12	Cash	6
Quail	9	Sling	3	Lathe	21	Hut	121
Wren	83	Clerk	29	Drill	52	Top	60
Duck	36	Spy	1	Vise	14	Malt	10
Swan	14	Age	20	Hinge	1	Rock	105
Hen	4	Shelf	7	Rasp	5	Spruce	67
Geese	12	Crown	9	Nut	10	Food	20
Finch	20	Stroke	4	Screw	43	Pound	126
Hawk	111	Bell	10	File	26	Clock	3
Jay	24	Stool	72	Glue	5	Harp	105
Stork	10	Golf	153	Awl	18	Cot	2
$\bar{X} = 37.19$		$\bar{X} = 37.25$		$\bar{X} = 43.25$		$\bar{X} = 43.81$	
$S = 41.55$		$S = 46.55$		$S = 95.19$		$S = 47.09$	

Experimental Lists (cont.)

C		-	C		C		-	C	
Boat	145		Storm	100	Chin	10		Elf	11
Jet	24		Fog	45	Thumb	13		Pig	142
Ski	3		Gale	12	Knee	79		Wolf	55
Bike	85		Frost	9	Cheek	6		Lamb	26
Sleigh	1		Cloud	74	Tooth	53		Skunk	15
Cab	19		Sleet	173	Neck	120		Mouse	118
Ship	47		Haze	2	Throat	40		Fox	44
Cart	21		Mist	11	Waist	19		Colt	1
Sled	12		Breeze	4	Thigh	21		Mule	46
Truck	223		Ice	14	Back	37		Steer	7
Van	10		Drought	16	Tongue	44		Frog	3
Raft	3		Smog	7	Breast	22		Ox	6
Yacht	1		Dew	4	Hip	26		Deer	95
Jeep	25		Cold	48	Face	46		Calf	5
Skate	21		Wind	85	Wrist	25		Goat	76
Blimp	1		Clear	13	Hair	125		Bull	40
$\bar{X}$ = 40.06			$\bar{X}$ = 38.56		$\bar{X}$ = 42.88			$\bar{X}$ = 43.13	
S = 61.76			S = 47.76		S = 36.12			S = 43.93	

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